Chapter 8
Quantitative Modeling of Sustainability in Interorganizational Supply Chains

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Abstract The consideration of environmental and social aspects has become essential for the management of supply chains where decision-making is particularly supported by formal models. This chapter reviews interorganizational quantitative models for sustainable supply chain management (SSCM) by employing content and cluster analyses. The paper sample consists of 62 formal models that meet the selection criteria for this literature review. The selected articles are analyzed with regard to sustainability and supply chain management constructs derived from related conceptual literature. In pursuit of greater insight into model types in conjunction with stakeholder triggers for SSCM and sustainable risk management, this review confirms the preponderance of deterministic approaches focusing on the interplay of economic and environmental aspects while social indicators are broadly omitted. It is detected that stochastic approaches to model all factors of the triple bottom line of sustainability are missing so far. Moreover, the operationalization of stakeholder pressures and incentives as well as sustainability-related risks is underrepresented, which calls for further research in this respect.

Keywords Supply chain • Sustainability • Interorganizational • Formal modeling • Literature review • Cluster analysis

8.1 Introduction

The management of supply chains has evolved from the mere strive for economic targets related to efficiency, customer satisfaction, and competitive advantage (Cooper et al. 1997; Mentzer et al. 2001; Chopra and Meindl 2007) to the comprehensive concept of sustainable supply chain management (SSCM) that includes social and environmental aspects of the triple bottom line of sustainability (Elkington 1998). SSCM focuses on downstream material flows from suppliers to customers

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(Seuring and Müller 2008) and is distinguished from reverse logistics or remanufacturing which deal with upstream material flows (Fleischmann et al. 1997) or closed-loop supply chain management (CLSCM) that includes forward and reverse material flows (Guide and van Wassenhove 2009).

A large majority of SSCM studies is based on conceptual or empirical research (Carter and Rogers 2008; Carter and Easton 2011), and thus quantitative models are needed to operationalize the conceptualized constructs (Golicic et al. 2005). In contrast to numerous quantitative approaches for reverse logistics, remanufacturing, and CLSCM (see reviews of Fleischmann et al. 1997; Guide and van Wassenhove 2009; Ilgin and Gupta 2010; Govindan et al. 2015), formal SSCM models are found less often (Min and Kim 2012). Although the company-internal supply chain needs to be distinguished from supply chains and networks of externally linked firms (Chen and Paulraj 2003), related reviews on formal SSCM modeling take a broad perspective on firm-specific, interorganizational, and macroeconomic approaches (see reviews of Seuring 2013; Brandenburg et al. 2014; Brandenburg and Rebs 2015).

As a result, more clarity is needed about how formal models can support decision-making for the sustainable management of forward supply chains on the interorganizational level. This chapter elaborates on this research gap and presents a systematic review of related papers. A particular focus is put on sustainability risks, on sustainable supplier management, and on stakeholder pressures and incentives for SSCM. The remainder of this chapter is structured as follows. The next section gives a brief review of related literature and is followed by the employed research methodology. Subsequently, the results of analysis are presented. The chapter concludes by summarizing and discussing the major findings.

8.2 Literature Background

Within the last couple of years, numerous reviews of SSCM and CLSCM papers were published. Apart from reviews that exclusively focus on empirical studies (e.g., Gold et al. 2010a, b; Carter and Easton 2011), 12 reviews include formal models in the paper sample. As illustrated in Table 8.1, these reviews can be categorized with regard to the research focus, the supply chain management (SCM) perspective, and the underlying sustainability perception as well as with regard to the research methods that are employed in the reviews.

Only two of these reviews are limited to environmental aspects, while all other reviews include social factors. For most reviews, the sampling process is based on structured keyword search, and content analysis is the method of choice. A large majority of reviews do not limit their focus on sustainability in forward supply chains but takes into account reverse flows or CLSCM. A clear focus on SSCM is taken by Seuring and Müller (2008), Seuring (2013), Brandenburg et al. (2014), and Brandenburg and Rebs (2015).

Table 8.1 Overview of related literature reviews

Author(s) and year	Sample size	Focus		SCM perspective		TBL aspect		Research method	
		General	Models	Direction	Focused level	Environmental	Social	Keyword search	Content analysis
Carter and Rogers (2008)	n/a	X		Undisclosed	Undisclosed	x	x		
Seuring and Müller (2008)	191	X		Forward	Undisclosed	x	x	x	x
Min and Kim (2012)	519	X		Closed loop	Undisclosed	x	x	x	x
Ilgin and Gupta (2010)	540		X	Closed loop	Undisclosed	x			x
Dekker et al. (2012)	60		X	Closed loop	Undisclosed	x			
Tang and Zhou (2012)	56		X	Closed loop	Undisclosed	x	x		
Hassini et al. (2012)	87		X	Closed loop	Undisclosed	x	x	x	x
Seuring (2013)	36		X	Forward	Undisclosed	x	x	x	x
Winter and Knemeyer (2013)	456	X		Closed loop	Undisclosed	x	x		x
Brandenburg et al. (2014)	134		X	Forward	All levels	x	x	x	x
Govindan et al. (2015)	382	X		Closed loop	Undisclosed	x	x	x	x
Brandenburg and Rebs (2015)	185		X	Forward	All levels	x	x	x	x

Brandenburg et al. (2014) inform about formal modeling approaches for different supply chain levels, where company-specific or macroeconomic models are not excluded. Seuring (2013) takes into account the model purpose, i.e., the different relationships of sustainability goals, and distinguishes between (i) win-win(-win) approaches that simultaneously improve social, environmental, and economic factors, (ii) trade-offs between these three factors, and (iii) models that aim at achieving a minimum performance with regard to socio-ecological aspects.

In their seminal review on SSCM, Seuring and Müller (2008) develop a framework that identifies *pressures and incentives for SSCM* caused by legal authorities and customers as key stakeholders. Moreover, they point out the strong relevance of *sustainable risk management* and *sustainable supplier management*. Risk management for SSCM was further conceptualized by identifying distinct practices (Beske and Seuring 2014). These dimensions of analysis have been applied to review quantitative models for SSCM on different supply chain levels (Brandenburg and Rebs 2015). However, approaches to model these constructs on the interorganizational level are not focused so far.

This brief overview summarizes trends and shortfalls of literature reviews on SSCM models:

- Structured keyword search and content analysis are adequate elements of a rigorous literature review process.
- Literature reviews that focus on forward SSCM models are found comparably seldom.
- Structured analyses of related literature should take into account how the relationships of the different sustainability goals are reflected in formal SSCM models.
- There is limited knowledge about how formal models can support decision-making for SSCM on the interorganizational level.
- Assessments of quantitative SSCM research approaches have neglected the question on how to include sustainability risks, sustainable supplier management, or pressures and incentives for SSCM into formal SSCM models on the interorganizational level.

The observed shortfalls result in two research questions of the study presented in this chapter:

1. How do formal SSCM models support decision-making on the interorganizational level?
2. How are sustainability risks, sustainability aspects in supplier management and stakeholder pressures, and incentives for SSCM integrated into formal SSCM models?

8.3 Methodology

In accordance with previous reviews, a content analysis of model-based SSCM research papers sampled by keyword search is conducted to answer these research questions. As suggested by Seuring and Gold (2012), the process of content analysis comprises four steps: (1) material collection, i.e., creating the paper sample, (2) descriptive analysis of the paper sample, (3) selection of structural dimensions and analytic categories for content analysis, and (4) evaluation of the paper sample according to the structural dimensions and analytic categories.

Methodological rigor is ensured by executing a systematic sampling process in a replicable and reliable way. Selecting the structural dimensions and analytic categories deductively contributes to construct validity. Furthermore, two researchers are involved in the paper coding process in order to achieve inter-coder reliability and internal validity. To strengthen external validity, the review results were presented and discussed at international scientific conferences and workshops.

The paper sample is based on a comprehensive review of 134 quantitative models for SSCM by Brandenburg et al. (2014). All 38 papers that propose interorganizational models were chosen for the study at hand and have been complemented by another 9 papers from a more recent paper sample of a related literature review by Brandenburg and Rebs (2015). Additionally, 14 relevant publications from a review of green logistics models (Dekker et al. 2012) as well as one additional paper obtained by journal-specific search are considered. In total, the sample of reviewed manuscripts comprises 62 papers. The sample papers have to focus on the forward supply chain and sustainability aspects in a formal model. Moreover, papers have to be published in English peer-reviewed scientific journals within the last 20 years (i.e., 1994–2013).

Descriptive analysis informs about the distribution of papers over time and over journals as well as about the geographical regions in which the authors' institutions are located. Results of descriptive analysis help in identifying temporal developments, relevant journals, and geographical foci.

The framework for content analysis, which is displayed in Table 8.2, comprises the structural dimensions and analytic categories that are defined deductively from related scientific publications and inductively in the course of analysis of the paper sample (Mayring 2008). The structural dimensions can be divided into four sections. Deductively defined modeling dimensions include the *model type* (Shapiro 2007) and *model purpose*, i.e., goal relationships between the three sustainability criteria (Seuring and Müller 2008; Seuring 2013). Supply chain management dimensions are defined deductively to elaborate on the SCOR *process of analysis* (Supply Chain Council 2008), the *level of analysis*, and the *primary actor of analysis* (Halldórsson and Arlbjørn 2005) and inductively with regard to *function of analysis* and the *industry focus*. The sustainability dimension is analyzed based on

Table 8.2 Structural dimensions and analytic categories selected for content analysis

Structural dimension	Analytic categories
Modeling dimensions	
Model type[a]	Descriptive-deterministic, descriptive-stochastic, normative-deterministic, normative-stochastic
Model purpose[a]	Win-win(-win), trade-off, minimum performance, not applicable
SCM dimensions	
Level of analysis[a]	Dyad, chain, network
Actor of analysis[a]	Manufacturer, carrier, wholesaler, retailer, warehousing, other, various, not applicable
Process of analysis[a]	Plan, source, make, deliver, return, not applicable
Function of analysis[a]	Logistics, network design, pricing, production, sourcing, SCM, technology and IT, various, not applicable
Industry focus[a]	Agriculture, apparel, automotive, chemicals and pharmaceuticals, electronics, energy, food and beverages, metal, pulp/paper, retail, transportation, various, not applicable
Sustainability dimension	
TBL dimensions[a]	Economic, environmental, social, economic-environmental, socioeconomic, socio-environmental, holistic
SSCM dimensions	
Pressures and incentives[b]	Government, customers, other stakeholders
Risk management[b]	Economic risks, environmental risks, social risks
Supplier management[b]	Supplier selection, environmental standards, social standards

[a]Single classification only
[b]Multiple classification possible

the *triple bottom line* (*TBL*) of sustainability (Elkington 1998). The sustainable supply chain dimensions are deduced from a conceptual framework for SSCM by Seuring and Müller (2008) that comprises stakeholder *pressures and incentives* for SSCM, sustainability *risk management*, and sustainable *supplier management*.

The paper sample is evaluated by counting the frequencies of occurrence of the analytic categories outlined above. As a result, the numbers allow to understand which constructs are particularly relevant for research and which ones are underrepresented. Furthermore, multivariate statistical analyses have been conducted to unveil correlations between analytic categories, since this approach has proven useful in related studies that employ content analysis (see, e.g., Wolf 2008; Gold et al. 2010a, b). Cluster analysis (Backhaus et al. 2008) is executed as TwoStep Cluster (TSC) analysis in SPSS® 22.0 to identify groupings of sample papers that feature the same combinations of analytic categories. In addition, contingency analysis (Backhaus et al. 2008) was tested for selected combinations of categories, but it did not lead to statistically significant results due to the sample size.

8.4 Results

8.4.1 Descriptive Analysis

The *distribution of publications* per year and journal is depicted in Table 8.3. It shows that model-based SSCM research evolved after 2000 and more strongly since 2008. The recent strong growth of publications was fostered by several reviews and conceptualizations on SSCM at that time (e.g., Srivastava 2007; Svensson 2007; Carter and Rogers 2008; Seuring and Müller 2008) which triggered intense scientific discourse on the operationalization of environmental and social criteria in SCM by formal models.

The *geographical analysis of the author's institutional affiliations* reveals that contributions from North America (29 counts) and Europe (28 counts) are prevailing and followed by Asian research institutions (16 counts) and articles authored by researchers with Latin American and Australian institutional affiliation (2 counts each). Fourteen of these papers result from intercontinental research cooperation. Papers written at African research institutes were not detected.

8.4.2 Content Analysis

Content analysis is structured into the *modeling dimensions*, the *sustainability dimension*, the *SCM dimensions*, and the *SSCM dimensions.*

8.4.2.1 Modeling Dimensions

The analysis of the *model type* (see Table 8.4) shows that deterministic models (54 papers) are prevailing in contrast to only eight stochastic models. Furthermore, the majority of sample papers suggests normative models (39 papers) in distinction from descriptive models (23 papers). These findings point to the objective of optimizing SSCM performance rather than only descriptively exploring the

Table 8.3 Distribution of articles per year and journals

Year	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	Total
IJPE	–	–	–	–	–	–	–	–	1	–	–	–	1	1	1	–	1	1	5	5	16
JCLP	–	–	–	–	–	–	–	–	–	1	1	1	1	–	2	1	1	–	–	3	11
IJPR	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1	2	2	–	1	1	8
EJOR	–	–	–	–	1	–	–	–	1	–	1	–	–	–	2	–	–	–	2	–	7
Other	–	–	–	1	–	–	–	2	–	1	–	2	–	1	1	2	3	5	1	1	20
Total	–	–	–	1	1	–	–	2	2	2	2	3	2	3	7	5	7	6	9	10	62

Table 8.4 Results from content analysis of the model type

	Deterministic	Stochastic	Total
Descriptive	17	6	23
Normative	37	2	39
Total	54	8	62

Table 8.5 Results from content analysis of the model purpose

Model purpose	Number of papers
Win-win	6
Trade-off	45
Minimum performance	1
Not applicable	10
Total	62

complexities of supply chains. On the other hand, the paucity of stochastic models suggests that adding uncertainties to these complexities is still underrepresented.

The frequencies of *model purposes*, i.e., goal relationships between TBL dimensions, are displayed in Table 8.5 and indicate the dominance of balancing economic and environmental (or social) aspects by trade-offs (45 papers). Win-win situations are modeled in six papers, while only one paper accounts for minimum performance standards. The structural dimension is not applicable for ten papers, which include purely environmental models that do not integrate economic or social factors.

Modeling trade-offs most often involves a balance between costs and emissions. Win-win situations can be reached, for instance, by the reduction of both cost and material input (e.g., Corbett and DeCroix 2001). Minimum standards are modeled by pollution limits (Maider 2008).

8.4.2.2 Supply Chain Management Dimensions

The results for each of the five structural dimensions are shown in Table 8.6. Most models consider a manufacturing company (15 papers) as *primary actor* or various actors (23 papers) without primarily focusing on one of them. Eight papers focus on carriers, but retailers and distributors are addressed by only one model each. Strikingly, warehousing and wholesalers are not modeled by any of the sample papers.

The prevalent *level of analysis* is a network (41 papers), followed by dyads (12 papers) and chains (9 papers). The observed focus on networks mirrors the interwoven supply structures that exist in industrial practice and illustrates the attempts to develop decision-support tools for such complex contexts.

Table 8.6 Results from content analysis of SCM constructs

Primary actor of analysis		Level of analysis		Process of analysis		Function of analysis		Industry focus	
Carrier	8	Chain	9	Plan	21	Logistics	15	Automotive	2
Distributor	1	Dyad	12	Source	8	Network design	11	Energy	7
Manufacturer	15	Network	41	Make	–	Pricing	1	Food and bev.	7
Retailer	1			Deliver	11	Production	2	Metal	3
Warehousing	–			Return	–	Sourcing	8	Retail	2
Wholesaler	–			n/a	22	SCM	12	Transportation	8
Various	23					Technology and IT	3	Other[a]	5
n/a	14					Various	4	Various	3
						n/a	6	n/a	25
Total	62	Total	62	Total	62	Total	62	Total	62

[a]One paper each: agriculture, apparel, chemicals and pharmaceuticals, electronics, pulp/paper

About one third of all papers (22 papers) do not focus on a particular *process of analysis*. The remaining models most often support supply chain planning processes (21 papers) which is not surprising since quantitative models represent the backbones of advanced planning systems. Papers that quantitatively assess sourcing (8 papers) and delivery (11 papers) processes are settled at the interface of an organization to its suppliers and customers, respectively.

The dominant *functions of analysis* are related to logistics (15 papers) or SCM (12 papers), which represent approaches to coordinate and control interorganizational supply chain processes. Furthermore, network design (11 papers) and sourcing (8 papers) decisions are supported by formal SSCM models. Technology-related models (three papers) or approaches with an exclusive focus on production (two papers) are underrepresented. Regarding the *industry of analysis*, the transportation sector (eight papers), the food and beverages industry, as well as energy provision (seven papers each) are most often in focus. Twenty-five papers do not address a specific industry, and the remaining 15 models deal with different sectors.

In addition to the one-dimensional analysis of observed construct frequencies, a two-dimensional TSC analysis is conducted to understand which *model type* is applied for the assessment of a particular *level of analysis*. The analysis of this combination of structural dimensions yields four clusters. As shown in Table 8.7, clusters 1 and 2 comprise normative-deterministic models that mainly focus on the network level. The remaining twelve network-related papers (clusters 3 and 4) include seven descriptive-deterministic and five stochastic models. This indicates that optimization of networks is yet more important than just describing them. Moreover, it is found that uncertainty added to network-related models is implemented by descriptive-stochastic models (four papers).

Table 8.7 Cluster analysis of model type and level of analysis

Cluster		1	2	3	4
Cluster size		8	29	17	8
Level of analysis	Dyad	5	–	4	3
	Chain	3	–	6	–
	Network	–	29	7	5
Model type	Descriptive-deterministic	–	–	17	–
	Descriptive-stochastic	–	–	–	6
	Normative-deterministic	8	29	–	–
	Normative-stochastic	–	–	–	2

Table 8.8 Results from content analysis of TBL dimensions

TBL dimensions	Number of papers
Purely environmental	8
Purely social	–
Economic-environmental	38
Socioeconomic	3
Socio-environmental	–
Holistic	13
Total	62

8.4.2.3 Sustainability Dimensions

The analysis of the *sustainability dimensions* of the triple bottom line of sustainability (see Table 8.8) suggests that a majority of models assesses eco-efficiency (38 papers) or exclusively focuses on environmental factors (8 papers). In contrast, social aspects (3 papers) are almost completely neglected, but 13 models incorporate all 3 TBL dimensions holistically.

To get further insight into the preferred *model type* for focused or holistic modeling of *TBL dimensions*, a second TSC analysis yields three clusters as depicted in Table 8.9. Cluster 1 includes all 13 holistic TBL models that are deterministic and mainly normative (8 of 13 papers), thus striving for optimization of all three TBL dimensions without taking uncertainty into account. The lack of stochastic holistic TBL models (2 of 13 papers) can be explained by their inherent complexities that drastically increase the model size and require larger computational capacities to solve such kinds of models. The remaining 29 focused normative-deterministic models are grouped in cluster 2. Cluster 3 contains the remaining 20 focused models that are either descriptive-deterministic or stochastic.

Table 8.9 Cluster analysis of model type and holistic or focused TBL dimensions

Cluster		1	2	3
Cluster size		13	29	20
TBL	Holistic	13	–	–
	Focused	–	29	20
Model type	Descriptive-deterministic	3	–	14
	Descriptive-stochastic	2	–	4
	Normative-deterministic	8	29	–
	Normative-stochastic	–	–	2

Table 8.10 Results from content analysis of pressures and incentives for SSCM

Pressure and incentive for SSCM	Formalized
Government[a]	17
Customers[a]	9
Other stakeholders[a]	2
All factors	2
Not modeled	39

[a]Multiple classification possible

Table 8.11 Cluster analysis of model type and pressures and incentives for SSCM

Cluster		1	2	3	4
Cluster size		15	22	17	8
Pressures and incentives	Holistic	2	–	–	–
	Focused	13	–	4	4
	None	–	22	13	4
Model type	Descriptive-deterministic	–	–	17	–
	Descriptive-stochastic	–	–	–	6
	Normative-deterministic	15	22	–	–
	Normative-stochastic	–	–	–	2

8.4.2.4 Sustainable Supply Chain Management Dimensions

The frequencies of formally modeled *pressures and incentives* (see Table 8.10) indicate that a considerable amount of models does not integrate any stakeholder triggers for SSCM. However, it is remarkable that governmental and other regulatory pressures and incentives are most prominent (17 papers) followed by customer requirements (9 papers) and other stakeholders (2 papers).

A third TSC analysis is carried out for a combined assessment of the *model type* and the *pressures and incentives for SSCM*. This analysis results in four clusters (see Table 8.11). Cluster 1 consists of all 15 normative-deterministic models that take

Table 8.12 Results from content analysis of SSCM risks

SSCM risks	Formalized
Economic risks[a]	14
Environmental risks[a]	9
Social risks[a]	5
Holistic risk management	4
Not modeled	46

[a]Multiple classification possible

Table 8.13 Cluster analysis of model type and SSCM risks

Cluster		1	2	3	4
Cluster size		8	29	15	10
SSCM risks	Holistic	4	–	–	–
	Focused	2	–	–	10
	None	2	29	15	–
Model type	Descriptive-deterministic	–	–	15	2
	Descriptive-stochastic	6	–	–	–
	Normative-deterministic	2	29	–	6
	Normative-stochastic	–	–	–	2

into account pressures and incentives, while the remaining 22 normative-deterministic models that belong to cluster 2 and most descriptive-deterministic models in cluster 3 (13 of 17 papers) do not consider those triggers. Cluster 3 comprises the remaining four descriptive-deterministic models that only focus on single pressures and incentives and furthermore. Cluster 4 groups the eight stochastic models, four of them reflecting pressures and incentives. These results suggest that so far pressures and incentives are predominantly measured in a deterministic way and that normative approaches prevail among them.

The integration of *SSCM risks* (see Table 8.12) into quantitative models is observed in only 16 papers. In these models, the consideration of economic (14 papers) and environmental (9 papers) risks dominates, while social risks are formalized in only five models.

Combining *model type* and *SSCM risks* for a fourth TSC analysis leads to four clusters (see Table 8.13). Cluster 1 consists of normative-deterministic and descriptive-stochastic models that take into account holistic or single aspects of sustainability-related SCM risks. A larger portion of normative-deterministic models (29 papers) and most descriptive-deterministic models (15 papers) exclude SSCM risks and are grouped into clusters 2 and 3. The fourth cluster comprises the remaining two stochastic models and eight deterministic models that reflect risk aspects in SSCM. It can be concluded that normative-deterministic models are more adequate to assess sustainability risks in SCM than descriptive-deterministic ones.

Table 8.14 Results from content analysis of sustainable supplier management

Sustainable supplier management	Number of models
Supplier selection[a]	15
Environmental standards[a]	9
Social standards[a]	4
All factors	4
Not modeled	47

[a]Multiple classification possible

Moreover, stochastic models are equally suitable for modeling sustainability risks. However, the overall small number of papers that present model-based approaches for sustainable supply chain risk management indicates the need for further research.

A large majority of 47 modeling papers does not consider the *sustainable management of suppliers* (see Table 8.14). Sustainability in supplier selection is formalized in 15 models that support supplier selection decisions. Models that operationalize supplier management with regard to environmental standards are suggested by nine papers, and four publications present models that reflect social factors in supplier management. Since this structural dimension allows multiple classifications and because categorization as "focused" or "holistic" is not applicable in this case, cluster analysis was not employed for the combination of *model type* and *sustainable supplier management*. Overall it can be concluded that model-based decision-support tools for sustainable supplier management which consider both environmental and social standards for supplier selection are still scarce.

8.5 Discussion

In accordance with Seuring (2013) and Brandenburg et al. (2014), SSCM modeling is identified as a comparably young field of research with a strongly increasing relevance over the last 5 years. In contrast to company-specific or macroeconomic approaches to sustainability in supply chains, nearly all formal SSCM models for the interorganizational level were published after 2001. Similar to the findings of Hassini et al. (2012), the results of content analysis reveal a preponderance of operations research journals in comparison to SCM-related periodicals. Surprisingly, the *Journal of Cleaner Production* has a considerably lower relevance for this interorganizational model-based SSCM research. This is in contrast to findings of broader literature reviews on SSCM models at various levels of analysis (Min and Kim 2012; Hassini et al. 2012; Seuring 2013; Brandenburg et al. 2014). As observed by Brandenburg et al. (2014), most formal SSCM models are published by North American or European research institutions.

The examination of modeling dimensions shows that normative models are more often employed than descriptive ones and that stochastic models are most underrepresented. This is in line with findings by Brandenburg et al. (2014), but normative models in the paper sample at hand prevail in a greater proportion. Thus, interorganizational approaches seem to be more focused on optimizing performance according to distinct objectives rather than only describing the state and development of SSCM-related processes and performance.

While most SSCM models aim at trade-offs between sustainability dimensions, approaches that contribute to win-win situations or minimum performance standards are seldom observed. Similar results were obtained by Seuring (2013), whereas Seuring and Müller's (2008) comprehensive review of conceptual, empirical, and model-based SSCM research detected a dominant orientation toward win-win situations.

Most observations of the SCM dimension confirm findings of Brandenburg et al. (2014). Formal SSCM models most often support planning processes and focus on manufacturing companies as well as various or unspecified actors while neglecting distributors, wholesalers, and retailers. The functional emphasis is put on general SCM or more specifically on logistics, sourcing, and network design. Decision-support tools for the interorganizational SSCM are surprisingly often applied in the transportation sector, the food and beverages industry, and the energy sector. This observation is in contrast to Brandenburg et al. (2014) who found many applications in the electronics industry and in the agriculture sector.

The analysis of the sustainability dimension clearly shows that formal SSCM models most often comprise environmental factors, while social aspects are widely neglected. Quantitative approaches that consider all TBL dimensions are found comparably seldom, and mostly deterministic models are employed for these holistic approaches. Overall, these observations are in line with conclusions by Seuring (2013) and Brandenburg et al. (2014).

The novelty of the study at hand is the assessment of interorganizational SSCM models and their elements that represent pressures and incentives for SSCM, sustainable risk and supplier management. Stakeholders' pressures and incentives, particularly governmental regulations, are comparably often reflected in formal SSCM models. This confirms the findings of a broader review that includes firm-specific and interorganizational as well as macroscopic SSCM models (Brandenburg and Rebs 2015). However, these governmental pressures and incentives are less often operationalized in quantitative approaches than being elaborated in conceptual and empirical studies for SSCM. In nearly every second paper reviewed by Seuring and Müller (2008), regulations from legal authorities, customer demands, or responses to other stakeholders are considered in context to SSCM. Similarly, supplier management for risks and performance has a higher relevance for SSCM research in general than for related formal models in particular. Seuring and Müller (2008) have detected that every third SSCM research paper reflects cost- or complexity-related barriers and several supporting factors, such as management, monitoring, or reporting systems, for SSCM. In contrast, the study at hand shows that sustainability risks or the sustainable management of suppliers plays subordinate roles in related model-based research.

8.6 Conclusion

In this chapter, 62 formal models for the sustainable interorganizational management of supply chains were reviewed. Content analysis and cluster analyses were performed to elaborate recent developments and future trends of related research. Four recommendations for future research are derived from the findings of this study:

1. More stochastic approaches are needed for model-based SSCM research. Especially in context to sustainability risks, which stem from uncertainties, stochastic methods could prove their advantages compared to deterministic ones.
2. The imbalance between environmental and social factors needs to be resolved. Sustainability aspects of supplier management can be seen as one application area for models that support socially responsible decision-making in supply chains.
3. The focus of SSCM models should move from assessing trade-offs between sustainability goals to determining win-win(-win) situations regarding the three dimensions of the TBL of sustainability.
4. The application area for formal SSCM models should be broadened to technology-related industries. Although qualitative approaches to decision-support systems are often applied in the automotive or in the chemicals and fuel industries, formal SSCM models are less often employed in these sectors.

Overall it is concluded that quantitative approaches to support sustainable decision-making on the interorganizational supply chain level offer large potential for research and application.

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